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I, Roger Walter GRAY MA, DPhil, CPhys,
translator to RWS Group Ltd, of Europa House, Marsham Way, Gerrards Cross, Buckinghamshire, England, do solemnly and sincerely declare that I am conversant with the English and French languages and am a competent translator thereof, and that to the best of my knowledge and belief the following is a true and correct translation of the PCT Application filed under No. PCT/FR2003/002761.

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Control valve for a fluid circuit, and circuit comprising this valve

The invention relates to the field of multiway valves for a fluid circuit, in particular for a cooling circuit for the internal combustion engine of a motor vehicle. It also relates to a fluid circulation circuit, in particular a cooling circuit for the internal combustion engine of a motor vehicle, comprising this valve.

More specifically, the invention relates to a control valve for a fluid circulation circuit, comprising a body having a cylindrical lateral wall defining a cylindrical housing, at least two tubes through which the fluid can enter or leave the body, a rotary adjustment device mounted to rotate in the cylindrical housing of the body about an axis, this adjustment device being able to assume various angular positions in order to control the circulation of fluid between the tubes.

Valves of this type are already known and they have a body comprising an end wall into which opens a fluid inlet and a cylindrical lateral wall into which open fluid outlets at axial heights and in angular positions chosen with respect to the axis of rotation of an adjustment device which can rotate about an axis of rotation.

A valve of this type has many disadvantages. Its overall size is considerable. Moreover, it does not make it possible to connect a large number of circulation ways for the fluid.

The object of the present invention is precisely to provide a control valve for a fluid circulation circuit which overcomes these disadvantages.

These aims are achieved according to the invention in that all the tubes open into the cylindrical lateral wall of the body.

By virtue of this characteristic, the overall size, in particular the overall axial size of the valve, is reduced. Moreover, it is possible to connect a large number of ways to the cylindrical periphery. Thus, one control valve according to the invention may replace a number of prior art valves, for example two four-way valves.

In a preferred embodiment, the tubes are arranged radially with respect to the cylindrical lateral wall.

This arrangement makes it possible to further increase the possible number of valveways.

The tubes may be distributed over a single level.

However, in a specific embodiment, the tubes are distributed over more than one level.

Thus, the tubes may be distributed over two, three or more levels. This embodiment is particularly appropriate where the valve is to contain a large number of ways, for example six or more than six. Thus, the overall diametral size of the valve can be kept small, in combination with a small overall axial size.

Furthermore, the invention relates to a fluid circulation circuit, in particular a cooling circuit for a motor vehicle internal combustion engine. Such a circuit is traversed by a cooling fluid which circulates in a closed circuit under the action of a circulation pump. Such a cooling circuit comprises a number of branches, including a branch which contains a radiator for cooling the engine, a branch which constitutes a bypass of the radiator for cooling the

engine and a branch which contains a radiator, also known as a unit heater, used for heating the vehicle cabin.

The invention relates to a fluid circuit comprising a control valve according to the invention, the tubes of which are connected to the various branches of the circuit. According to a specific embodiment, the circuit is provided in the form of a high-temperature circuit for cooling a motor vehicle internal combustion engine, comprising a main pump for circulating the fluid, a bypass line and a heating line containing a unit heater, and a low-temperature circuit comprising a low-temperature pump, a heat-exchange module consisting of a high-temperature heat-exchange section permanently integrated with the high-temperature cooling circuit, of a low-temperature heat-exchange section permanently integrated with the low-temperature cooling circuit, and of an assignable section which can be integrated either with the high-temperature heat-exchange circuit or with the low-temperature heat-exchange circuit, the control valve being connected to the heat-exchange module, to the high-temperature circuit and to the low-temperature circuit in such a way as to integrate the assignable heat-exchange section either with the high-temperature circuit or with the low-temperature circuit, according to an operating parameter of the engine.

Other additional and/or alternative characteristics of the invention are listed below:

- the rotary adjustment device has pockets which are able to place two or more than two tubes in communication with one another;
- the valve comprises a cylindrical sealing ring arranged between the cylindrical lateral wall of the body and the rotary adjustment device;
- the rotary adjustment device has a convex rounded shape and the sealing ring has a concave rounded shape

which is complementary with the shape of the rotary adjustment device;

- the ring has a stop means which allows it to be rotationally immobilized with respect to the body of the valve;
- the stop means is a protuberance which fits into a corresponding housing formed in the body;
- a seal, in particular an O-ring seal, is provided around at least one pocket of the rotary device in order to isolate the fluid circuits from one another;
- the valve has seven tubes distributed over two levels;
- one of the levels has three tubes, while the other level has four tubes;
- the rotary device has three pockets;
- the rotary device additionally has a through duct.

In particular, the valve according to the invention will have two stages, each including three ways, and a rotary device having pockets making it possible to place said ways in communication in pairs, depending on its angular position. All or part of said pockets will be oriented substantially parallel to the axis of rotation of said rotary device and/or will be inclined with respect thereto so that the ways of two different stages can be placed in communication. According to this embodiment, a six-way valve is obtained in which both the overall radial and axial size is particularly advantageous.

Other characteristics and advantages of the present invention will become apparent on reading the description below of exemplary embodiments given by way of illustration with reference to the appended figures. In these figures:

figure 1 is a perspective view of a control valve according to the present invention;

figure 2 is an exploded view of the valve represented in figure 1;

figure 3 is a sectional view of the valve represented in figures 1 and 2;

figure 4 is a sectional view of the valve represented in figure 3, taken along the line IV-IV;

figure 5 is an external view of a second embodiment of a valve according to the present invention comprising tubes distributed over two levels;

figure 6 is a left-side view of the valve represented in figure 5;

figure 7 is a rear view of the valve represented in figure 5;

figures 8 and 9 represent two perspective views of the valve of figures 5 to 7;

figure 10 is an exploded view of the valve represented in figures 5 to 9;

figure 11 is a sectional view taken along the line XI-XI of figure 6;

figure 12 is a view of a cooling circuit for a motor vehicle internal combustion engine, comprising two four-way valves;

figure 13 is a view of the cooling circuit represented in figure 12, in another operating configuration;

figure 14 is a view of a cooling circuit for a motor vehicle internal combustion engine, comprising a control valve according to the present invention, with the view being represented in the same configuration as the circuit of figure 12;

figure 15 is a view of the cooling circuit of figure 14, represented in the same configuration as the cooling circuit of figure 13;

figure 16 is a sectional view taken along the line XVI-XVI of figure 6, in a configuration corresponding to figure 14; and

figure 17 is a sectional view, identical to figure 16, of the two-control valve of the invention, represented in the configuration

corresponding to the circuit of figure 15.

Figures 1 to 4 represent a first embodiment of a control valve according to the invention. The valve has a body denoted by the general reference 2, consisting of a cylindrical lateral wall 4 and of an end wall 6 (figure 4). The body 2 has a general shape which is generated by revolution about an axis XX. The body 2 has six tubes 8 which open radially into a cylindrical housing 10 of axis XX (figure 2). In the embodiment represented, the axes 12 of the tubes 8 are coplanar (figure 3). In addition, the tubes are uniformly distributed at 60° to one another at the periphery of the lateral cylindrical wall 4. These characteristics are not imperative and it would be possible for the tubes 8 not to be coplanar, or else it would be possible for them not to be uniformly distributed at the periphery of the lateral cylindrical wall 4. However, according to an important characteristic of the invention, all of the tubes 8 open out on the cylindrical wall 4. None of them is situated on the end wall 6 (figure 4).

Inside the cylindrical housing 10 is housed a rotary adjustment device 14, the diameter of which corresponds substantially to the internal diameter of the cylindrical housing 10 (figures 2 to 4). The adjustment device 14 is extended by a rod 16 directed along the axis XX. This rod 16 passes through a central opening belonging to a circular cover 18 which is screwed onto a flange 20 of the body 2 of the control valve by means of fastening screws 22, with interposition of an O-ring seal 24 (see figure 2). The rotary adjustment device 14 is able to be rotated about the axis XX by drive means (not shown) which may consist, for example, of a stepper motor capable of bringing the rotary device 14 into a multiplicity of different positions, either by successive increments or continuously.

The rotary device 14 has pockets 26 (three in the example represented) which are able to place the tubes 8 in communication with one another. These pockets are formed by cutouts made in the rotary device 14 which open out at the periphery of the latter. Thus, as can be seen in figure 3, the tubes 8 are distributed in pairs. They communicate with one another by way of the pockets 26. Thus, one of the tubes of each pair can constitute an inlet for the fluid, while the other tube of the pair constitutes an outlet for this fluid. By rotating the rotary device through an angle of 60° in one or other direction, it is possible to place two different adjacent tubes in communication.

A sealing ring 30 is interposed between the rotary device 14 and the lateral cylindrical wall 4 of the body 2 (figure 2). Advantageously, the rotary device 14 has a convex rounded shape and the sealing ring 30 has a concave rounded shape which is complementary with the shape of the rotary device 14. There is thus self-centering of the rotary device 14 with respect to the body 2 of the valve. The self-centering allows the valve to be placed in the desired angular position. This solution also has the advantage of minimizing the friction surfaces required for sealing, thus limiting the operating forces. No part of the rotary device 14 is in contact with the body 2. The sealing ring 30 (figure 2) has circular openings 32 corresponding to the inlet or the outlet of the tubes 8 (six in the example represented). The openings 32 are equipped with lip seals to provide sealing between the ring 30 and the body 2. In addition, the sealing ring 30 has an opening 34 in a nonoperational part so as to facilitate mounting thereof on the rotary device 14 and also demolding thereof. The sealing ring 30 also has a protuberance 36 (figure 2) which gets housed in a housing (not shown) in the body 2 of the valve so as to prevent the sealing ring 30 from rotating with respect to the body.

Figures 5 to 11 represent a second embodiment of a control valve according to the present invention. This valve is distinguished from that which has been described above through the fact that the inlet or outlet tubes are distributed over more than one level, two in the example represented.

As in the case of the first embodiment, the valve has a cylindrical body 2 bounded by an end wall 6 and a cylindrical lateral wall 4 of axis XX. The cylindrical lateral wall 4 defines a cylindrical housing 10. The housing is closed by a cover 18 which is fastened by screws 32 (four in the example represented) which fasten the cover 18 to a flange or collar 20 forming part of the body 2. A seal, for example an O-ring seal 24, is interposed between the cover 18 and the flange 20.

The body 2 has seven tubes all arranged, according to an important characteristic of the invention, on the cylindrical lateral wall 4. In this embodiment, the tubes are distributed over two levels, namely a first level, which will be referred to as lower level because it is closer to the end wall 6 of the body, and a second level, which will be referred to as upper level because it is closest to the opening of the body 2 and to the cover 18.

Four tubes have been arranged at the first level. In the figures, these tubes respectively bear the references 50, 52, 54, and 56. Three tubes have been arranged on the second level or upper level. In the figures, these tubes have been respectively denoted by the references 58, 60 and 62.

The tubes 50 and 58 are associated with one another. The tube 50 forms part of the lower level, while the tube 58 forms part of the upper level. These two tubes

therefore allow communication between the lower level and the upper level. Furthermore, the tubes 60 and 62, both of which belong to the upper level, are also paired with one another.

A rotary device, denoted in its entirety by the general reference 80 (figures 10 and 11), is arranged inside the cylindrical housing 10 of the body 2. It is mounted to rotate about the longitudinal axis XX of the body 2. The device 80 comprises a generally cylindrical hollow body 82 of axis XX. The body 82 is extended by a rod 26 directed along the axis XX, which passes through a central opening 27 belonging to the cover 18. An O-ring seal 17 (see figure 10) is interposed between the rod 26 and the opening 27. As described previously, the rotary device 80 is able to be rotated about the axis XX by drive means (not shown) capable of bringing it into a multiplicity of different angular positions, either by successive increments or continuously.

Three pockets are formed within the cylindrical body 82. These pockets are denoted by the references 84, 86 and 88. The pocket 84 extends over the two levels and it is able to place the tubes 50 and 58 in communication with one another. It is also able to communicate with the tube 52.

The pocket 86 likewise extends over two levels. It is approximately L-shaped. It is able to place the tubes 54 and 62 (see figure 14) in communication, and also the tubes 54 and 56 (see figure 15).

The third pocket 88 is situated only on the upper level of the body of the rotary device 80; it is able to place the tubes 60 and 62 in communication (see figure 15).

Finally, the rotary adjustment device 80 has a through duct 90 which, in the example represented, passes

through it diametrally. The duct 90 is intended to switch part of one of the circuits into another (see figures 14 and 15). It is situated at the lower level of the rotary device 80.

A sealing ring, denoted in its entirely by the reference 100, is interposed between the rotary device 80 and the cylindrical wall 4 of the body 2. Openings, the shape and number of which correspond to the number of pockets formed in the rotary adjustment device 80, are provided in the sealing ring 100 (figure 10). Since the rotary device has three pockets, the sealing ring also has three openings tailored to each of these pockets. These openings have been denoted by the references 102, 104 and 106. The opening 102 corresponds to the pocket 84, the opening 104 to the pocket 86 and the opening 106 to the pocket 88. Furthermore, two circular openings 110 corresponding to the two ends of the duct 90 have been provided in the sealing ring 100.

Sealing means are provided over the periphery of each of the openings described above. These sealing rings could consist, for example, of lips. However, in the example represented, they consist of O-ring seals, such as the seal 112 (figure 10).

Figures 12 and 13 represent a fluid circulation circuit. This circuit consists, on the one hand, of a high-temperature cooling circuit 120 of a motor vehicle internal combustion engine 121 and, on the other hand, of a low-temperature cooling circuit 122 intended for the cooling of equipment 124 of the motor vehicle, for example an intercooler or a condenser forming part of the air-conditioning circuit for the motor vehicle cabin.

The high-temperature cooling circuit 121 is traversed by the fluid for cooling the engine 121, which is

circulated by a high-temperature main circulation pump 126, the fluid heated by the engine leaving the latter via an outlet 128 which is connected to the inlet of a three-way valve 130. The valve 130 has three tubes which are connected to three branches of the high-temperature cooling circuit, namely a branch 132 which comprises a high-temperature cooling radiator, which will be described subsequently, a branch 134 which forms a cooling radiator bypass and a branch 136 which comprises a unit heater 138 used for heating the vehicle cabin.

The valve 130 makes it possible to control the flows of fluid into the aforementioned branches so as to optimize the temperature of the internal combustion engine and the heating of the cabin. When starting the engine from cold, it allows the fluid to be circulated in the bypass branch 134 without passing through the radiator. During this starting phase, it is possible to pass all or part of the fluid flow into the unit heater 138 if it is desired to heat the cabin. When the temperature of the fluid has reached or exceeded a given threshold, the fluid passes into the high-temperature cooling radiator.

The low-temperature cooling circuit 122 consists of a loop in which the fluid is circulated by a low-temperature pump 140. It passes through a heat exchanger 124, mentioned above, for example an intercooler or a condenser forming part of an air conditioning circuit for the motor vehicle cabin. It is then cooled in a low-temperature exchanger 142. The fluid circulation circuit of figures 12 and 13 has a heat-exchange module formed by two rows of heat-exchange tubes.

The first of these rows constitutes the low-temperature cooling radiator 142 mentioned above. This row of tubes is permanently integrated with the low-temperature

cooling circuit 122. The way in which the second row of tubes is formed is more exceptional in the sense that the second row of tubes is divided into two parts, namely a part 144 constituting a high-temperature heat-exchange section used for cooling the high-temperature circuit 120, especially the internal combustion engine 121. The section 144 is permanently integrated with the high-temperature cooling circuit 120.

Moreover, the second row of tubes of the heat exchange module comprises an assignable heat-exchange section 146. This assignable section can be integrated either with the high-temperature cooling circuit 120 or with the low-temperature cooling circuit 122. Below a certain temperature value for the cooling liquid, for example 105°C, the assignable heat-exchange section 146 forms part of the low-temperature cooling circuit. The cooling capacity of this circuit is thus increased, which makes it possible to improve its output, for example to improve the output of the air-conditioning circuit.

If the temperature of the engine-cooling fluid increases above the critical value, it is necessary to increase the cooling capacity for the internal combustion engine 121. It is for this reason that the assignable heat-exchange section 146 is then integrated with the high-temperature cooling circuit, as represented in figure 13. To this end, the fluid circulation circuit has two four-way valves 150.

As can be observed in figure 12, the two four-way valves 150 are connected in such a way that the assignable heat-exchange section is traversed by the cooling fluid which circulates in the loop 122 before entering the heat-exchange row 142, constituting a low-temperature heat exchange. The heat-exchange area is thus made up of the sum of the assignable section 146 and of the row of tubes 142.

By contrast, in the configuration of figure 13, which corresponds to the operation above a critical temperature for the cooling fluid, the four-way valves 150 are oriented in such a way that the fluid of the low-temperature cooling circuit 122 passes through a bypass line 152, avoiding the assignable heat-exchange section 146. Moreover, the four-way valves 150 make it possible to direct a portion of the cooling fluid from the high-temperature circuit 120 to the heat-exchange section 146 through a branch 154, as depicted by the arrow 156. Thus, the high-temperature section 144 and the assignable heat-exchange section 146 are mounted in parallel and their cooling capacities are combined to cool the motor vehicle internal combustion engine 121.

However, as can be observed, two valves 150 are necessary in this embodiment in order to interconnect the high-temperature circuit 120 and the low-temperature circuit 122. This results in additional cost and complexity together with an increase in the overall size. The control valve of the invention is particularly advantageous in an application of this type because it makes it possible to replace the two four-way valves 150 with a single valve, with the result being a reduction in both the cost and the overall size.

Figures 14 and 15 represent a fluid circulation circuit consisting of a high-temperature cooling circuit 120 and of a low-temperature cooling circuit 122 which are analogous to the circuits represented in figures 12 and 13, in which fluid circulation circuit the two four-way valves 150 have been replaced with a single control valve according to the present invention.

In figures 12 to 15, the identical parts of the fluid circulation circuit have the same references.

The control valve of the invention is in accordance with the embodiment which has been described above with reference to figures 5 to 11. Consequently, the tubes of this valve are distributed over two levels, namely a lower level denoted by the reference 160 and an upper level denoted by the reference 162 (figures 14 and 15). To make the drawing clearer to understand, the levels 160 and 162 have been represented separated from one another. It must be understood that this is a schematic representation. In reality, these two levels are arranged one above the other as has been explained in the preceding description of this embodiment of the valve of the invention.

Figure 14 corresponds to the configuration of the circuit represented in figure 12, namely a configuration in which the temperature of the fluid for cooling the internal combustion engine is below a critical value, for example 105°C. In this configuration, the high-temperature cooling radiator consists only of the high-temperature heat-exchange section 144 forming part of the second row of heat-exchange tubes of the heat-exchange module described above. Consequently, the assignable heat-exchange section 146, which completes the second row of tubes of the heat-exchange module, forms part of the low-temperature cooling circuit 122.

The three-way thermostatic valve 130 is oriented in such a way that the cooling fluid is directed toward the branch 132 (arrow 133), toward the tube 50 forming part of the lower level 160 of the control valve of the invention. The cooling fluid passes from the lower level 160 to the upper level 162 through the pocket 84 which, as has been explained above, allows these two levels to be placed in communication with one another. The fluid leaves through the tube 58, which then constitutes an outlet tube, to be directed by the line 170 (arrow 172) toward the high-temperature heat-

exchange section 144. After it has been cooled, the fluid conventionally arrives back at the engine 121 and the circulation of the fluid is repeated.

As far as the low-temperature cooling circuit 122 is concerned, the cooling fluid moved by the low-temperature circulation pump 140 passes through the heat exchanger 124, for example an air-conditioning circuit condenser, and enters the lower level 160 of the control valve of the invention through the tube 56, which then constitutes an inlet tube. The fluid passes through the rotary device 80 by virtue of the through duct 90 and emerges into the tube 52 forming an outlet tube, as depicted by the arrow 174.

The fluid then enters the assignable heat-exchange section 146, as depicted by the arrow 176, and then, after having passed through this heat-exchange section, enters the upper level 162 of the control valve through the tube 62.

In this configuration of the cooling circuit, the rotary device 80 is oriented angularly in such a way that the pocket 86 is situated facing the inlet tube 62. As has been explained above, the pocket 86 makes it possible to pass the fluid from one level to the other, in this instance from the upper level 162 to the lower level 160. The fluid thus leaves through the tube 54 constituting an outlet tube, as depicted by the arrows 178, to enter the low-temperature heat exchanger 142, more specifically the row of tubes of the heat-exchange module which constitutes the low-temperature cooling radiator still forming part of the circuit 122. The fluid then repeats the same circuit. As can be observed, and in the manner as has been described with reference to figure 12, the bundle of tubes 142 and the assignable heat-exchange section 146 are thus mounted in series and traversed successively by the low-temperature cooling fluid. Their cooling capacities are

combined.

Figure 16 is a sectional view of the control valve of the invention represented in an angular position of the rotary device 80 corresponding to figure 14. In figure 16, it can be seen (arrow 180) how the pocket 84 places the tube 50 and the tube 52 in communication.

Figure 15 represents the cooling circuit of figure 14 in a configuration in which the temperature of the cooling fluid is above the critical temperature defined above, for example 105°. In this configuration, it is necessary to cool the internal combustion engine 121 of the motor vehicle more powerfully. For this purpose, it is necessary to transfer the assignable cooling capacity 146 from the low-temperature cooling circuit 122 to the high-temperature cooling circuit 120.

The three-way thermostatic valve 130 is oriented in such a way that the fluid circulates through the branch 132 (arrow 133) toward the inlet tube (50) forming part of the lower level (160) of the control valve of the invention. However, in this configuration, the angular orientation of the adjustment device 80 is different. It is still the pocket 84 which is situated facing the tubes 50 and 58. However, in this configuration, the pocket 84 places the inlet tube 50 simultaneously in communication with the tubes 58 and 54. There is therefore one inlet tube, namely the tube 50, and two outlet tubes, namely the tubes 54 and 56. In this example, the tubes are not placed in communication exclusively in pairs, but one tube is placed simultaneously in communication with two different tubes.

In other exemplary embodiments, one could have a reverse situation in which a number of inlet tubes are placed in communication with a single outlet tube. Generally, one pocket of the rotary device 80 can place

one inlet tube in communication with two or more than two outlet tubes. Consequently, the cooling fluid leaves the upper level 162 through the outlet tube 58 to pass through the high-temperature heat-exchange section 144, as described above. However, in addition, a portion of the cooling fluid leaves through the outlet tube 52 to cross through the assignable heat-exchange section 146 which is thus placed in parallel with the high-temperature heat-exchange section 144. This circulation corresponds exactly to the situation which has been described with reference to figure 13. Thus, as has been said, the cooling capacities 144 and 146 placed in parallel with one another are combined, which makes it possible to cool the engine more powerfully.

As far as the low-temperature cooling circuit 122 is concerned, the cooling fluid circulated by the low-temperature circulation pump 140 passes through the heat exchanger 124, and then, via the inlet tube 56 enters the lower level 160 of the control valve in the angular orientation of the rotary device 80 represented in figure 15, the pocket 86 places the tube 56 in communication with the tube 54 such that the fluid enters (arrows 178) the low-temperature heat-exchange section (142) of the heat-exchange module of the fluid circuit.

Figure 17 represents a sectional view of the control valve in the angular orientation of the rotary device 80 corresponding to figure 15.

After it has passed through the assignable heat-exchange section, the fluid enters the valve through the inlet tube 62 situated in the upper level 162, then enters the pocket 88 of the device 80 and leaves through the tube 60 constituting an outlet tube, before returning, in the conventional way, toward the high-temperature circulation pump 126 in order once more to

pass through the internal combustion engine 121 of the vehicle. The same circulation of the fluid is then repeated.

Many variant embodiments are possible for the valve of the invention and its application is not limited to a fluid circuit of the type described above.